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WILLIAM LASSELL, Esq., F.R.S., President, in the Chair.

Duncan Darrock, Esq., 5 Beaufort Gardens, and
Edwin George Monk, Esq., York,

were balloted for and duly elected Fellows of the Society.

On Telescopic Observations of the Phenomena seen in contiguity with the Moon's Limb during Eclipses of the Sun, and the Results which have been therefrom deduced. By Professor Grant.

The application of the spectroscope to observations of the envelope of red matter encompassing the solar photosphere, an envelope which has been named *the chromosphere*, has given rise to occasional allusions to the anterior telescopic observations of the same phenomenon, as revealed during eclipses of the Sun, and to the results hence deduced. I beg leave to submit to the Society a few remarks on this subject.

Admitting the existence of such an envelope and its thickness to be inconsiderable, the question arises, under what appearance should it present itself during eclipses of the Sun.

Since the apparent diameter of the Moon sometimes exceeds, sometimes equals, and sometimes falls short of, the apparent diameter of the Sun, it is obviously possible that the existence of the envelope may be occasionally revealed by the phenomenon of a circle of red light surrounding the Moon's disk during slightly total eclipses of the Sun. No instance, however, of such an occurrence has been recorded in the annals of telescopic observations of solar eclipses.*

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* Secchi supposes the envelope encompassing the solar photosphere to have a thickness included between 10″ and 15″. Let us assume its mean thickness to be 12″·5. Now, since the apparent diameter of the Moon may be equal to, or greater or less, than the apparent diameter of the Sun, it is quite conceivable that a total eclipse of the Sun may occur during which the envelope may be seen

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In solar eclipses generally it is plain that the existence of such an envelope may be *partially* revealed by the appearance of an arc of red light at the part of the Moon's limb where it just covers or slightly overlaps the Sun's disk. This partial covering or slight overlapping of the Sun's disk may occur — 1°, during a total eclipse; 2°, during a nearly total eclipse; 3°, during an annular eclipse; 4°, during a nearly annular eclipse. Let us consider each of these cases separately.

1. *Total Eclipses.*—If the observer be situated in the line of central totality the Moon would just cover the solar disk at the instants of immersion and emersion, and there should be visible a corresponding arc of red light contiguous to the Moon's limb, namely, first at the eastern and then at the western limb, having its centre in each case coincident with the point of interior contact of the solar and lunar disks. If the observer proceeds northwards the Moon's centre will be depressed by parallax, and the points of interior contact will gradually recede upon the upper limb, approaching each other and finally merging together at the apex when the observer has reached the northern limit of totality. Similarly, if the observer travel southwards, the points of interior contact will gradually shift upon the lower limb, approaching each other, and finally merging together at the apex when the observer has reached the southern limit of totality.

2. *Nearly Total Eclipses.*—If the observer be situated a little beyond the northern or southern line of totality, the arc of red light may be visible at the part of the upper or lower limb of the Moon where it slightly overlaps the solar disk.

3. *Annular Eclipses.*—The results as regards the shifting of the points of interior contact are here the same as in the case of total eclipses, except that, as the observer proceeds *northwards*, the points of interior contact approach each other on the *lower* limb instead of the *upper*, finally merging at the apex, while a result, the reverse of this, occurs when he travels towards the *southern* limit of the annular phase.

4. *Nearly Annular Eclipses.*—If the observer be situated a little beyond the northern or southern limit of the annular phase, the arc of red light (modified perhaps, in aspect by the presence of Sunlight) may be expected to be seen at the part of the Moon's limb where it slightly overlaps the solar disk.

It is manifest then that in total eclipses of the Sun the interior contacts of the Sun and Moon, and the consequent slight over-

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in the form of a red circle encompassing the Moon's limb. Such a condition may be realised on the 30th of November, 1872, when, according to the *Nautical Almanac*, there will be a total eclipse of the Sun, the maximum duration of which on the Earth's surface is 47 seconds. In Latitude 35° 6′ S. and 139° 25′ East Longitude the duration on the central line is stated to be 26 seconds, whence it may be inferred that the envelope would be visible, in the form of a complete circle, during about twenty seconds of time. Mr. Hind has remarked that if we assume the tabular values of the Sun and Moon to be exact, this eclipse will be *annular* near the times of beginning and ending on the Earth' surface.

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lapping of the Moon beyond the solar disk, may occur at any part of the Moon's limb, being dependent in this respect on the position of the observer, with respect to the line of central totality. Of course the more nearly the apparent diameters of the Sun and Moon approach to an equality, the narrower will be the limits of totality, and the more rapidly will the points of contact shift upon the Moon's limb for any given change in the position of the observer relative to the central line of totality. On the occasion of the total eclipse of 1842 (which cannot be considered a *large* eclipse) the Moon's shadow passed over some of the most densely populated and easily accessible regions of Southern Europe, and experienced observers were stationed at a great number of places ranging between the two extreme limits of the shadow.

The remarks which I have made with respect to the shifting of the points of interior contact in the case of total eclipses of the Sun, are equally applicable to annular eclipses. As regards nearly total eclipses or nearly annular eclipses, the slight overlapping of the Moon will obviously occur either at the upper or the lower limb.

I would remark, further, that in total eclipses of the Sun observations made at the two extreme limits of totality are especially favourable for observing the arc of red light, since the Moon glides tangentially over the arc, and lingers upon it, whereas in the case of the observer being situated in the centre of the shadow, the Moon advances in a direction which is normal with respect to the arc (at its middle point), and, consequently, passes more rapidly over it. The observations made in France at the two opposite limits of totality during the eclipse of 1842 strikingly illustrate this circumstance.

A similar remark is obviously applicable to annular eclipses.

It was thus, by examining all the recorded observations of solar eclipses available to me from the beginning of the seventeenth century down to the annular eclipse of 1847, analysing and arranging them according as they were total, annular, nearly total, or nearly annular, and confronting the results with each other, that I was led, in the winter of 1850–51, to announce the existence of an envelope of matter superposed upon the solar photosphere.* I shall now quote a few of the observations included in this inquiry.

Total Eclipses of the Sun.

Halley, who observed the eclipse of 1715 at London, remarked that two or three seconds before the emersion, a long and very narrow streak of a dusky but strong red light seemed to colour the dark edge of the Moon on the western side where the Sun was just coming out.

I shall cite four observations of the phenomenon made during

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* *History of Physical Astronomy*, pp. 358–411. This work was published in separate parts or numbers, in connexion with a republication of the works of the Library of Useful Knowledge. The first number appeared in September 1848, and the work was finally published complete in March 1852.

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the eclipse of 1842, those of Schumacher and Radman made near the central line of totality, and those of Bérard and Guérin at the opposite limits. The observations of Schumacher were made at Vienna, which was situated towards *the north* of the central line of totality. A mean of the results derived from the tables of Burckhardt and Damoiseau made the distance of the upper limbs of the Sun and Moon to be 13″·66. Schumacher states that a little before the emersion of the Sun there appeared near the part of the Moon's disk from behind which the first ray of light was about to issue, *a narrow streak of rose-coloured red light*, which extended perhaps over an arc of 70° or 80° along the Moon's limb, and which disappeared with the luminous ring and the rose-coloured mountains as soon as the first ray of the Sun darted forth. The observations of Radman were made at Padua, which was situated towards *the south* of the line of central totality. These observations have an exceptional value in so far as the question under consideration is concerned, Professor Belli, of the University of Padua, having assigned to Radman the task of specially noting the phenomena visible at the Moon's limb immediately after the total immersion of the Sun, and immediately previous to its emersion. Radman states that no sooner was the Sun totally covered than there appeared a very slender streak of a reddish light surrounding somewhat less than half the circumference of the Moon disposed equally on each side of the place where the last ray of the Sun was extinguished. He adds that it soon vanished, but that it reappeared immediately previous to the emersion of the Sun. The observations of Bérard, who was a Captain in the French Marine and a Corresponding Member of the French Institute, were made at Toulon. Any one may convince himself by referring to the track of the Moon's shadow, as laid down in the *Connaissance des Temps* for 1842, that Toulon was situated almost exactly upon the *southern* line of totality. The observation of Captain Bérard is on this ground so important, that I will give his words in the original. He says,—

"Pendant tout le temps de l'éclipse totale on vit au de là du bord de la Lune, près de la region où le Soleil émergea, une bande rouge très mince dentelée irregulièrement ou comme sillonné ça et là de crevasses."

We have here a precise description of the *sierra* so well known to observers of subsequent eclipses. The visibility of the phenomenon during the whole time of obscuration is in perfect accordance with the position of the place of observation at one of the extreme limits of totality.

At Visan, which was very nearly upon the *northern* line of totality, Guérin, a French observer, perceived immediately after the immersion of the Sun, seven or eight very distinct indentations which might have been taken for so many stars of different magnitudes. They were redder, but less brilliant, than *Mars*. If the whole periphery of the Moon's disk had been bordered with similar luminous points it would have presented the appearance of

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a box of ebony garnished with rubies. The phenomenon continued visible during the whole time of totality.*

Annular Eclipses.

Maclaurin, who observed the annular eclipse of 1737, states that a little before the formation of the ring, a remarkable point or speck of pale light appeared near the middle of the part of the Moon's limb that was not yet come upon the disk of the Sun, and that a gleam of light more faint than this light seemed to be extended from it to each horn. This phenomenon was seen about fifteen seconds previous to the projection of the whole body of the Moon upon the solar disk. Lord Aberdour, who observed the same eclipse, remarked that a narrow streak of a dusky red light coloured the dark edge of the Moon immediately before the ring was completed, and after it was dissolved. Henderson, who observed the eclipse of 1836 at Edinburgh, states that previous to the formation of the annulus, when the cusps were about 30° or 40° apart, an arc of faint reddish light was seen extending between them. The appearance lasted several seconds.† Dr. Forster, who observed the eclipse of 1847 at Bruges, mentions that there was visible a very remarkable luminous arc or ridge of light, differently coloured from the rest of the Sun, extending along and immediately on the limb of the Moon between the cusps. From the brief notice of this observation it is not very clear whether it related to an annular or a nearly annular eclipse. It would follow from an inspection of the track of the Moon's penumbra, as laid down in the *Connaissance des Temps* for 1847, that Bruges was situated a very little distance beyond the northern limit of annularity.

Nearly Annular Eclipses.

Short, who observed the eclipse of 1748, at Aberdour Castle, where it was very nearly annular (a little beyond the southern limit), states that when the interval between the Moon's cusps did not exceed one-seventh of the Moon's circumference, a brown light was plainly perceived both by Lord Morton‡ and himself to extend from each cusp about one-third of the whole distance between them. He remarked also at the extremity of this brown light (which came from the western cusp) a larger quantity of light than elsewhere. The illustrious Bessel thus describes the appearance presented during the eclipse of 1836, May 15, as observed at the Königsberg Observatory, which was situated a very short distance beyond the northern limit of the annular phase:—"About twenty-five seconds before the nearest approach of the centres of the two bodies, I perceived near the extremity of the upper cusp a luminous point which, without having the brightness of the Sun, was very dis-

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* Guérin adds that the luminous points extended over an arc of about the sixth part of the Moon's circumference.

† Edinburgh was situated about midway between the central and northern line of the annular phase. The first annular contact took place at 167° from the vertex towards the west.

‡ A good amateur observer, the same person who, under the name of Lord Aberdour, observed the annular eclipse of 1737, *vide suprà*.

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tinctly visible with the powerful heliometer. As the cusps were then approaching each other, I hoped that the annulus was about to form, but this did not happen. With respect to the point which I have just alluded to, it became more luminous. Other similar points appeared which soon united together, and rendered visible all the part of the Moon's limb included between the extremities of the cusps."* Mr. Twining, an American, observed the eclipse of 1838 at New York. This eclipse was annular at Philadelphia, but failed very slightly in being so at the place where Mr. Twining observed it. He states that several minutes before the nearest completion of the ring, the fine cusps of the Sun's unobscured crescent were prolonged by a hair-breadth line of brightness totally diverse in colour and intensity from the Sun's disk. As the cusps approached the lines or threads of light shot round the Moon's edge between them rapidly, till at a certain time they met and joined in one, thus uniting the cusps.

The visibility of the phenomenon during sunshine, as thus exhibited in the case of annular and nearly annular eclipses, is fully confirmed by the observations of the annular eclipse of May 23, 1867, made in Dalmatia, at Barsecienne, a place situated on the northern limit of the annular phase. On that occasion Herr Kiha, an officer of the Austrian naval service, perceived a prominence near the extremity of the upper cusp 14·4 minutes before the formation of the ring, and was able to follow it during a further interval of 14·7 minutes.† The colour (*braünlich gelb*) which he ascribes to the object accords perfectly with the speck of pale light seen by Maclaurin during the annular eclipse of 1737, with the accumulation of brown light at a point intermediate between the cusps noticed by Short during the nearly annular eclipse of 1748, and furthermore with the observations of Bessel and Henderson in 1836, of Twining in 1838, and Forster in 1847.

In every instance, except one or two, it is expressly stated that the arc of red light was seen at the region of immersion or emersion,—in other words, at the region where the Moon's limb just covered, or slightly overlapped, the Sun's disk. In no instance is it stated to have been observed at any other part of the disk. In annular or nearly annular eclipses, the break observed in some instances in the arc extending from the cusps, is accounted for by the somewhat too great overlapping of the Moon, which would be most effective at the point midway between the cusps.

While engaged in this inquiry I endeavoured to show that the phenomena observed during solar eclipses, whether corona, streaks or patches of light, or prominences great or small, are

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* Secchi, in his recently published work *Le Soleil*, p. 213, remarks: "Bessel, observant une eclipse annulaire à Königsberg, avait vû le bord de la lune environné d'un circle rouge." This statement must not be accepted in a literal sense. The eclipse was *not* annular at Königsberg, although very nearly so, and most assuredly Bessel did not see the margin of the Moon surrounded by a red circle. The account of the observation which I have given is a translation of Bessel's own description of the phenomenon (*Ast. Nach.* vol. xiv. p. 115).

† *Ast. Nach.* No. 1647, p. 228.

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all solar phenomena. While the results of observation were either positively in favour of the solar aspect of the case or adverse to the lunar aspect, there did not appear to exist a shadow of a proof in support of the lunar origin of the phenomenon.

Seeing, then, that when a great number of solar eclipses, observed indifferently with respect to the limiting lines of the Moon's shadow or penumbra, are taken into consideration, the slight overlapping of the Moon takes place at all parts of the solar disk, and that wherever this overlapping really does occur, there is visible at the Moon's limb an arc or band of red light, the existence of such a margin of light becomes thus inductively traceable round the entire contour of the solar disk.

It was under the influence of a conviction forced upon me by these considerations that in the winter of 1850–51 I made the following announcement:—

"According to the usual theory of the physical constitution of the Sun, that body consists of an opaque nucleus, surrounded by an atmosphere in which are suspended, at different elevations, two enveloping substances of dissimilar physical properties, the lower envelope being imperfectly luminous, but capable, in a high degree, of reflecting light, while, on the other hand, the upper envelope forms a resplendent canopy of clouds, which are luminous in themselves, and constitute the source of the light diffused in every direction by the Sun. The observations of solar eclipses would seem to indicate that, above the luminiferous envelope, there exists *a stratum of nebulous matter* which is visible only by means of reflected light. Various interesting questions present themselves for solution in connexion with the admitted existence of such a stratum. In the first place, does *this third envelope* exercise an influence in the production of any of the other phenomena which have been disclosed by observations on the physical constitution of the Sun? M. Arago has very ingeniously suggested that the solar spots which exhibit the aspect of a penumbra without a nucleus, may arise from the superposition of masses of this nebulous matter above the luminiferous envelope. Secondly, the question arises, does any relation subsist between this non-luminous substance, which floats in the upper regions of the solar atmosphere, and either of the other two envelopes?

"Sir John Herschel, in his ingenious theory of the physical origin of the solar spots, supposes a perpetual circulation to be kept up in the solar atmosphere, analogous to that which, in the case of the terrestrial atmosphere, produces the phenomenon of the trade-winds. Now, is it not reasonable enough to suppose that such a circulation will have the effect of continually agitating the non-luminous matter constituting the envelope nearest the solid nucleus of the Sun, and throwing up masses of it above the luminiferous surface?

"This view of the subject, while it carries with it considerable probability, obviates the necessity of introducing into the theory of the physical constitution of the Sun, the idea of a third

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envelope independent of the two others. Future observations prosecuted more especially with reference to the positions of the solar spots during the occurrence of eclipses of the Sun, can alone be expected to throw light upon this interesting question." (*History of Physical Astronomy*, page 400.)

The passage which I have here quoted contains the announcement of a fact, and an attempt at an explanation of its physical cause. As regards *the fact*, I consider it to have been established by the observations on which it is founded. With respect to *the explanation*, it is a mere surmise which may or may not contain elements of truth.

In referring to this solution which I gave of the question of the band of red light seen during solar eclipses, I am far from maintaining that it is as perfect as it might be. The combination of the valuable results of telescopic observations of solar eclipses made subsequently to the annular eclipse of 1847, with the previously existing stock of results, would unquestionably improve the solution, and a better still might be obtained by a systematic placing of observers in determinate positions with respect to the limits of the track upon the Earth's surface of the Moon's shadow or penumbra; but now observations on a new principle are available which supersede the necessity of any such attempts.

The interest attached to the envelope of red matter encompassing the solar photosphere, and the importance with which it has been recently invested, are almost wholly due to the brilliant results which have been obtained by the application of the spectroscope to observations of the Sun. Still it appears to me to be desirable, in the interest of truth, that the series of carefully executed telescopic observations of solar eclipses anterior to the year 1848 should have accorded to them their due weight, and that their applicability to a legitimate explanation of some of the phenomena seen on such occasions should be fairly stated.

The Observatory,
Glasgow, November 1871.

In connexion with the foregoing remarks I append an extract from an account of my own observations of the total eclipse of the Sun of July 18, 1860, which I communicated to the Astronomer Royal in the autumn of 1860. The observations were made from a position (about twenty miles north of the line of central totality) on the Sierra de Tolonio, a lofty mountain range, a little to the south of Vitoria, overlooking the valley of the Ebro.

"At a distance of 60° to the right of the vertex, I perceived a third prominence. When first seen it resembled a small cone attached to the Moon's limb. As the Moon advanced over the Sun's disk, it gradually increased in dimensions until it finally attained an altitude of about $1\frac{1}{2}'$. In colour and general aspect it bore a close resemblance to the large prominence near the vertex. While I was engaged in examining the last-mentioned promin-

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ence I perceived several other very small peaks which had just come into view, and a few seconds afterwards the motion of the Moon disclosed a long stratum uniting them together at their bases, giving to the whole phenomenon the aspect of a *sierra* resting on the Moon's limb, and extending over an arc of about 20°. This continuous succession of prominences was intensely red, resembling in colour the most beautiful vermilion. The light was very much condensed, there being an entire absence of the streaks which characterized the larger prominences. The re-appearance of the Sun was preceded by an excessively narrow band of red light bounding the Moon's limb and connecting itself with the *sierra* previously observed. This long streak of light extended over an arc of about 25° on the Moon's limb. The reappearance of the first ray of the solar light resembled a bright star emerging at the Moon's limb. It occurred at $3^h\ 3^m\ 10^s$." *

On an Universal Equatoreal. By John Browning, Esq.

Wishing to employ the telescope used by Colonel Tennant for photographing the Solar Eclipse of 1868, for the purpose of photographing the next Solar Eclipse in India, it occurred to the Astronomer Royal that it would be a great advantage to have the instrument so made that it might be considered universal, and used in any latitude between the equator and 60° to 70° N. or S. of the equator. When the instrument had been altered so as to fulfil these conditions, I believe to the satisfaction of the Astronomer Royal, I saw that a more efficient instrument might have been made if it had been planned specially for this purpose. I have prepared for exhibition before the Society a model of such an instrument, and I am now making one of 10¼-in. diameter, for a gentleman at Sydney.

On reference to the diagram, the principle of construction will, I think, be evident.

The whole of the telescope, with the Polar axis, is carried by centres at E; large plates are attached to the sides of a cradle, which carries the Polar axis; AA is the Polar axis; BB the cradle in which it is carried; CC, an arc with a clamping arrangement, of which the adjusting screws are shown at FF; a clamp screw is hidden by the spur-wheels; when this screw is released, the angle of the Polar axis of the instrument may be changed from the horizontal to a nearly vertical position, or let to remain in any intermediate position between these, reclamped and finally adjusted by the capstan-screws FF; D is the clock, which, by means of a bevelled spur-wheel, gives motion to a wheel which revolves round the centre on which the Polar axis turns at E; this wheel, through the intermediation of two other wheels turns the driving-

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* Greenwich Mean Time. The observations were made with a Dollond Refractor of 2¾ inches aperture.